

IN THE UNITED STATES PATENT  
AND TRADEMARK OFFICE

APPLICATION FOR  
UNITED STATES UTILITY PATENT

**TUBULAR MONITOR SYSTEMS AND METHODS**

Extra Set Claims - 1-29 - For PTO Examiner

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55 CLAIMS:

1 1. A system for measuring parameters of a structure,  
2 the system comprising

3 a plurality of strain gauges emplaceable on the  
4 structure,

5 signal transmission apparatus associated with  
6 the plurality of strain gauges for transmitting signals  
7 therefrom indicative of measurements by the plurality of  
8 strain gauges to computer apparatus for processing  
9 signals from the strain gauges,

10 the plurality of strain gauges including at  
11 least three strain gauge apparatuses for providing  
12 axial strain measurements at each location of one of the  
13 at least three strain gauge apparatuses, and

14 computer apparatus for receiving signals from  
15 the transmitting apparatus indicative of the measurements  
16 of the at least three strain gauge apparatuses and for  
17 determining, based on said measurements, bending moment  
18 of the structure at a location of a plane including the  
19 at least three strain gauge apparatuses.

1 2. The system of claim 1 wherein the computer apparatus  
2 is programmed to calculate internal pressure of the  
3 structure based on strain measurements from the plurality of  
4 strain gauges.

1 3. The system of claim 1 wherein the computer apparatus  
2 is programmed to calculate bending direction of the  
3 structure at said location based on said measurements.

1 4. The system of claim 1 wherein the computer apparatus  
2 determines bending moment in real time.

1 5. The system of claim 4 wherein the computer apparatus  
2 is programmed to make a plurality of continuous determinations  
3 of bending moment in real time.

1 6. The system of claim 1 further comprising  
2 encasement material encasing the plurality of strain gauges.

1           7. The system of claim 6 wherein the encasement  
2 material comprises insulating material for enhancing  
3 uniformity of operation of the plurality of strain gauges  
4 during temperature changes.

1           8. The system of claim 6 wherein the encasement  
2 material comprises potting material.

3           9. The system of claim 1 further comprising  
1               each of the plurality of strain gauges  
2 comprises a fiber optic strain gauge.

3           10. The system of claim 1 further comprising  
4               display apparatus for displaying to an operator  
1 determinations of the computer apparatus.

1           11. The system of claim 1 further comprising  
2               alarm apparatus for warning an operator of the  
3 system that a maximum allowable stress on the structure has  
4 been reached, the computer apparatus programmed to calculate  
5 maximum allowable stress and in communication with the alarm  
6 apparatus.

1           12. The system of claim 1 further comprising  
2               temperature measurement apparatus for measuring  
3 temperature of the structure at the location of plurality of  
4 strain gauges.

5           13. The system of claim 12 wherein the temperature  
6 measurement apparatus comprises fiber optic strain gauge  
7 apparatus for measuring temperature.

1           14. The system of claim 12 wherein the computer  
2 apparatus is programmed to adjust said measurements for  
3 temperature changes indicated by the temperature measurement  
4 apparatus.

1           15. The system of claim 12 wherein the system includes  
2 temperature measurement apparatus for measuring temperature of  
3 the structure at the location of the plurality of strain  
4 gauges, pressure measurement apparatus for measuring internal  
5 pressure of the structure, and weight measurement apparatus  
6 for measuring weight of the structure; and the computer

7 apparatus is programmed to receive signals indicative of  
8 strain measurements from the plurality of strain gauges,  
9 temperature measurements from the temperature measurement  
10 apparatus, internal pressure measurements from the pressure  
11 measurement apparatus, and weight measurement from the weight  
12 measurement apparatus, and the computer apparatus is  
13 programmed to determine bending moment of the structure at the  
14 location of the plurality of strain gauges, stresses  
15 throughout the structure, maximum stress on the structure, and  
16 location of maximum stress on the structure.

1 16. The system of claim 1 wherein the plurality of  
2 strain gauges comprises at least one set of three fiber optic  
3 strain gauges including an axial strain gauge for measuring  
4 axial stress on the structure, a hoop strain gauge for  
5 measuring hoop stress on the structure, and a temperature  
6 strain gauge for measuring temperature of the structure.

1 17. The system of claim 16 wherein the at least one set  
2 of three fiber optic strain gauges is four sets spaced at  
3 ninety 90 degree intervals around the structure.

1 18. The system of claim 1 wherein the structure is from  
2 the group consisting of riser, subsea riser, lubricator, pipe  
3 support structure, tubular string, and lubricator stack.

1 19. The system of claim 1 further comprising  
2 a protective ring apparatus on the structure  
3 adjacent which is located the plurality of strain gauges.

4 20. The system of claim 19 wherein the protective ring  
5 apparatus is two spaced-apart rings between which are located  
6 the plurality of strain gauges.

7 21. The system of claim 19 wherein potting material  
8 encapsulates the plurality of strain gauges.

9 22. The system of claim 1 further comprising  
10 cover apparatus releasably connected to the  
11 structure over the plurality of strain gauges.  
12

13           23. A method for measuring parameters of a structure,  
14 the method comprising

15                       measuring parameters of the structure with a  
16 system, the system comprising a plurality of strain gauges  
17 emplaceable on the structure, signal transmission apparatus  
18 associated with the plurality of strain gauges for  
19 transmitting signals therefrom indicative of strain  
20 measurements by the plurality of strain gauges to computer  
21 apparatus for processing signals from the strain gauges, the  
22 plurality of strain gauges including at least three strain  
23 gauge apparatuses for providing axial strain measurements at  
24 each location of one of the at least three strain gauge  
25 apparatuses, and computer apparatus for receiving signals from  
26 the transmitting apparatus indicative of the measurements of  
27 the at least three strain gauge apparatuses and for  
28 determining, based on said measurements, bending moment of the  
29 structure at a location of a plane including the at least  
30 three strain gauge apparatuses.

31           24. The method of claim 23 wherein the computer  
32 apparatus is programmed to calculate internal pressure of the  
33 structure based on strain measurements from the plurality of  
34 strain gauges, the method further comprising

35                       with the computer apparatus, calculating said  
36 internal pressure.

1           25. The method of claim 23 wherein the computer  
2 apparatus is programmed to calculate bending direction of the  
3 structure at said location based on said measurements, the  
4 method further comprising

5                       with the computer apparatus, calculating said  
6 bending direction.

1           26. The method of claim 23 wherein the computer  
2 apparatus determines bending moment in real time, the method  
3 further comprising

4                       with the computer apparatus, determining said

5 bending moment in real time.

1 27. The system of claim 26 wherein the computer  
2 apparatus is programmed to make a plurality of continuous  
3 determinations of bending moment in real time, the method  
4 further comprising

5 with the computer apparatus, making said plurality  
6 of continuous determinations in real time.

1  
1 28. The method of claim 23 wherein the computer  
2 apparatus is programmed to calculate bending direction of the  
3 structure at said location based on said measurements and  
4 wherein the system includes temperature measurement apparatus  
5 for measuring temperature of the structure at the location of  
6 the plurality of strain gauges, pressure measurement apparatus  
7 for measuring internal pressure of the structure, and weight  
8 measurement apparatus for measuring weight of the structure;  
9 and the computer apparatus is programmed to receive signals  
10 indicative of strain measurements from the plurality of strain  
11 gauges, temperature measurements from the temperature  
12 measurement apparatus, internal pressure measurements from the  
13 pressure measurement apparatus, and weight measurement from  
14 the weight measurement apparatus, and the computer apparatus  
15 is programmed to determine, in real time, bending moment of  
16 the structure at the location of the plurality of strain  
17 gauges, stresses throughout the structure, maximum stress on  
18 the structure, and location of maximum stress on the  
19 structure, the method further comprising

20 with the computer apparatus, calculating in real  
21 time said bending direction, said bending moment, said  
22 stresses throughout the structure, said maximum stress, and  
23 said location of said maximum stress.

1 29. The method of claim 28 wherein the said bending  
2 direction, said bending moment, said stresses throughout the  
3 structure, said maximum stress, and said location of said  
4 maximum stress are displayed on display apparatus.